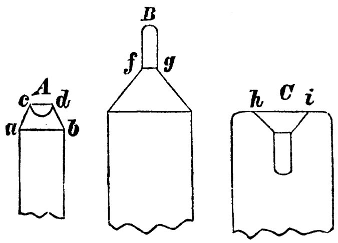
can be easily put in rotation ; *i* is a needle to rest in a hole in a piece of lead, to prevent oscillation. The dimensions given are : *a b*, 70 mm. ; *b c*, 36 mm. ; *d f*, 19 mm. The tubing openings were 8 mm. long and 6 mm. in diameter.

The sound-radiometer (fig. 4) is readily made. In cardboard about 8 mm. thick, holes are punched at intervals of 6 mm. with the punch of the form shown at *A*. When prepared in this way, the cardboard will be repelled if presented to the resonator with the small ends of the holes toward it, and attracted when reversed. To make these effects more marked, the punch and die shown at *B* and *C* may be



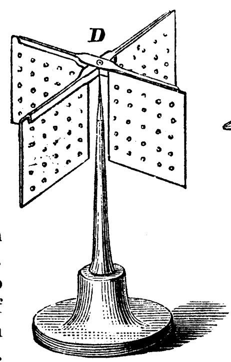


FIG. 4.

used on moistened cardboard to form conical holes with cylindrical ends. The conical holes alone show no effects. By arranging the pieces of pasteboard as in *D*, or better as in *E*, a rapid rotation may be obtained. The apparatus shown in fig. 5 is called a sound-wind-mill. A Helmholtz resonator, *a b*, is placed before the opening of the box-resonator. Out of the smaller end, *a*, a stream of air will be blown when the fork is vibrated, and its existence shown by the rotation of the windmill, *h k*. The dimensions of the Helmholtz resonator for *G* are : diameter, 80 mm. ; the opening at *b*, 16 mm. ; at *a*, 2 mm. This last is very important. It seems odd that the resonator with two openings may be replaced by such as shown at *R* with only one. The opening may face in any direction, provided the windmill is suitably placed, and still the mill will turn. When the opening is turned toward the resonator-box, the distance between the

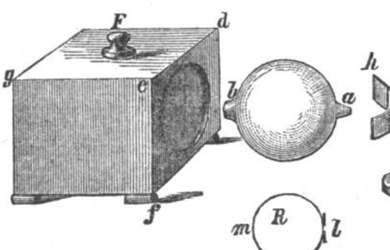


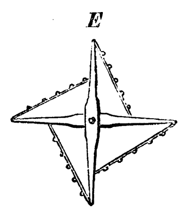
FIG. 5.

resonators may be as great as half a metre. The dimensions and form of the ball are important. A suitable one may be made by grinding off the top of a glass globe 50 mm. in diameter, and covering the opening with a very thin metal plate in which there is a hole 3.5 mm. across. The puffs of air coming from the opening *l* are vortex-rings, which may easily be shown by filling the ball with smoke.

By putting one of the wings of the sound-radiometer before the box-resonator with the larger ends of the holes facing it and at a distance of 2 cm. from it, the mill may be made to rotate by the puffs of air coming through the holes, which should be numerous.

AURORAL EXPERIMENTS IN LAPLAND.

MR. J. RAND CAPRON gives a brief account (*The observatory*, Sept.) of Professor Lemström's experiments, quite similar to that which has already appeared in SCIENCE. He thinks that Professor Lemström's conclusion, that the height of auroras "has been generally overestimated may probably open a lively discussion, as undoubtedly his dictum will that 'measurements of an aurora on a long base must be erroneous, as the observers never see the same aurora.'" He thinks, too, that the relation Professor Lemström believes himself to have proved, between movements of atmospheric electricity and the 'variations of the magnetic elements,' may be only apparent.



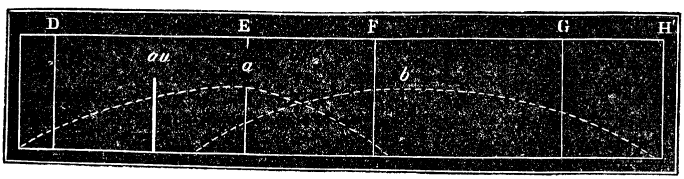
Mr. Capron believes that the experiments described did "collect and make apparent to the eye a true auroral glow, its spectroscopic character being at the same time tested and defined by experienced observers." He adds, "Yet one cannot help feeling something of regret that, if only for further assurance, the wave-length of some one line seen was not (as far as we are aware) absolutely determined, on some occasions at least, and that the observations appear to rest only on a small instrument presumably without scale."

Mr. Capron's article is important mainly for calling renewed attention to the phosphorescence, or fluorescence, theory of the principal (yellow-green) line of the aurora spectrum. This theory, first proposed by Angström, was advocated in the *Philosophical magazine* for April, 1875, by Mr. Capron, who is inclined to attribute the line to phosphorescence, apparently on the following grounds: 1°. The 'phosphorescent appearance' of the aurora ; 2°. The fact that phosphorescence is capable of giving quite sharply defined spectral lines, as shown by his observations with a phosphorescent vacuum tube ; 3°. The fact that the auroral line belongs to 'the principal region of phosphorescent light;' 4°. 'The observed circumstance that the electric discharge has a phosphorescent afterglow.'

Mr. Capron observed, moreover, that the auroral line lies in the region of a certain bright band in the spectrum of a phosphoretted hydrogen flame, though somewhat nearer the red end of the spectrum than is

the brightest part of this band, as shown in the accompanying figure.

"In this diagram (of a normal spectrum), curve *a* [which Mr. Capron calls the phosphorescence curve] is deduced from the spectrum of phosphoretted hydrogen, curve *b* from Professor Angström's spectrum of the violet pole of air-vacuum tubes; *a u* is the principal auroral line." This figure is apparently intended



to represent the facts under ordinary laboratory conditions; but Mr. Capron states, that according to Lecoq de Boisbaudran, when the flame of phosphoretted hydrogen is artificially cooled, the bands of the spectrum become intensified, and in such a way that the brightest portion of each band is shifted toward the red end of the spectrum. Mr. Capron appears to think, that, under the intense cold of the auroral regions, one of these bands might become the line *a u*.

E. H. HALL.

LETTERS TO THE EDITOR.

Secular increase of the earth's mass.

THE thoughtful and suggestive researches of Ebelmen and T. Sterry Hunt, on the chemical and geological relations of the earth's atmosphere,[1] have led me to some further deductions, which seem to increase the interest in this field of inquiry. The general tendency of these studies is to show that the chemical transformations in progress upon the earth involve the fixation of a larger volume of atmospheric constituents than could probably have ever existed in the atmosphere at one time, and that they must consequently have arrived from interplanetary space.

1. *The carbonates.* — It is generally agreed, as first shown by Hunt, that the carbonates of lime and magnesia have arisen chiefly through the interactions between carbon dioxide of the atmosphere, the decomposing silicates of the earth's crust, and the chloride of calcium of the ocean. The carbon dioxide has therefore been contributed by the atmosphere. To what does this contribution amount? We may assume, without material error, that the carbonates here in question are all calcium carbonate, with a specific gravity of 2.72. Then, the mean pressure of the atmosphere being about 14.7 pounds avoirdupois on a square inch, a little calculation shows that an amount of carbon dioxide in the atmosphere sufficient to double its pressure would yield only 8.627 metres of limestone. An amount sufficient to cause a pressure of 80 atmospheres would suffice for the formation of limestones equal to only a fortieth (.02265) of the hundred thousand feet which, for this purpose, may be assumed as the thickness of the stratified rocks. But a pressure of 80 atmospheres at a temperature of 30° C. produces liquefaction of carbon dioxide. The actual proportion of limestones and dolomites in the earth's crust is about one-eighth, as I have shown by recent studies. This amount would yield, by the liberation of all its carbon dioxide, a pressure of 441.6 atmospheres. If we consider the limestones and dolomites formed since the period of the coal-measures, the proportion required to yield, on the liberation of its carbon dioxide, a pressure of 80 atmospheres, would be only a twenty-second (.04469) of all the post-carboniferous strata. The actual proportion is about one-eighth, as for the whole stratified crust; and this would yield sufficient carbon dioxide to cause a pressure of 223.8 atmospheres.

It is not credible that such amounts of carbon dioxide have ever existed in the atmosphere at one time. During the larger part of the aeons of carbonate formation, animal life has existed in great abundance upon the earth; and this would have been impossible with 200 to 400 atmospheres of carbon dioxide present. As the proportion of this gas in the existing atmosphere is only $4\frac{1}{2}$ parts in 10,000 by weight, 200 atmospheres of the gas would be 444,000 times the present proportion. It is scarcely more credible that the pressure of 200 to 400 atmospheres would have been compatible with either vegetable or animal organization, so similar as it was fundamentally to modern organization. As this large amount of carbon dioxide cannot be supposed derived from the earth's crust, it must have been derived from interplanetary space. This would imply an addition to the earth's mass of .0003806, which is about $\frac{1}{2636}$ part of the present mass.

2. *The kaolinization of felspars.* — Hunt has shown that the kaolinization of a layer of 51.66 metres of orthoclase, or its equivalent of quartzo-felspathic rocks, would result in 23.7 metres of kaoline, and would use up 10,333 kilograms of carbon dioxide per square metre of surface. This is the weight of the atmosphere. Now, the whole amount of felspathic decomposition during the sedimentary ages must much exceed 500 metres in vertical thickness of kaolinic deposits. But 500 metres of kaoline represent 21.1 atmospheres of carbon dioxide; and, assuming the mass of the atmosphere at $\frac{1}{1200000}$ in relation to the earth, the carbon dioxide fixed in the processes of kaolinization would be .0000175826 of the total mass of the earth.

3. *Decay of hornblende, pyroxene, and olivine.* — According to Hunt, the decay of $10\frac{1}{3}$ metres of such minerals, or their equivalents in hornblendic and pyroxenic rocks, would yield carbon dioxide equal to 1 atmosphere: hence, if the earth's crystalline rocks have afforded 500 metres of hornblende and pyroxene, they must have fixed 48.387 atmospheres of carbon dioxide. This, in relation to the earth's mass, is 0000403209.

4. *Conversion of ferrous into ferric oxide.* As Ebelmen states, the conversion of 21,357 kilograms of ferrous oxide into 23,750 kilograms of ferric oxide would consume the whole of the 2,376 kilograms of oxygen in the atmosphere (more exactly, 1.007 atmospheres) covering a square metre. If, then, we suppose the existence over the earth of 1,000 metres of sediments derived from the decay of crystalline rocks containing only one per cent of ferrous oxide, weighing, according to Hunt, 25,000 kilograms, this is 1.052 times the amount requisite to fix the oxygen in 1.007 atmospheres; that is, 10 metres of ferric oxide represent the fixation of 1.059 atmospheres of

[1] See a memoir by T. Sterry Hunt in *Amer. journ. sc.*, May, 1880, where references are given to numerous other publications.